Use of steel bands in sternotomy closure: implications in high-risk cardiac surgical population

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Abstract

A retrospective-prospective descriptive and comparative study of two sternal closure techniques in a population of 621 patients divided into: group A, steel band closure (n=300) and group B, conventional technique closure (n=321), was carried out between January 2005 and December 2007 in order to describe and compare the results of both techniques in high-risk patients for sternal dehiscence and mediastinitis. Differences between both groups and association with risk factors were obtained using non-parametric tests for statistical analysis. No complications or mortality related to the use of the steel sternal bands were found. A statistically significant difference was found in the frequency of sternal dehiscence between both groups (P=0.022) in favor of group A. Although the frequency of mediastinitis was higher in group B, a statistically significant difference could not be established in terms of this complication. Sternal dehiscence was found to be a risk factor for mediastinitis. This study demonstrates that the use of steel bands for median sternotomy closure is a safe, reliable and reproducible technique. The frequency of sternal dehiscence significantly decreases with this technique in high-risk patients.

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1. Introduction

Sternalotomy healing complications such as instability, non-union, and bone or mediastinal infection, occur in 0.5–6% of the general population. In the high-risk population, these complications could increase from 12 to 20% [1-5] in association with a 14–47% mortality rate, particularly if mediastinitis is present [1].

Preoperative risk factors as well as intraoperative and postoperative aspects that lead patients to develop mediastinitis after a sternotomy have been widely explored; high body mass index (BMI), diabetes, smoking, chronic obstructive pulmonary disease (COPD), chronic renal failure (CRF), emergency surgery, length of surgery, prolonged stay in intensive care unit (ICU), re-intervention, and infection at another site, among others [3, 4].

There are many sternal closure options which include different materials and surgical techniques [4-9]. The steel wire has proven to be the most reliable and widely used sternotomy closure material, with a wide variety of wiring techniques [1].

The first report using sternal bands for sternal closure was made at the University of New York at Stony Brook Hospital. Since the publication of their work, many kinds of steel bands have been used with theoretical advantages over conventional wire closure [6].

Unfortunately, as expressed by Robiseck and Fokin in a recently published editorial in the European Journal of Cardiothoracic Surgery [10], differences between sternal closure techniques and materials had been mainly proved on experimental models that combined cadaveric bone, plastic or synthetic materials; these elements do not simulate real human sternal bone, neither the stress forces and situations in the postoperative period. This editorial calls attention to the high priority need for prospective studies under real human conditions that will provide recommendations about the benefits of one closure technique over another [10].

2. Materials and methods

Retrospective-prospective descriptive and comparative study performed at the cardiothoracic surgery service of the Medellin Clinic with the main objective of evaluating the frequency of sternal dehiscence and/or mediastinitis in high-risk patients for these events after sternal closure with peristernal steel bands (SternumBand®) compared to conventional closure with simple sternal wires. The study population was constituted by patients who fulfilled inclusion criteria during the period between January 2005 and December 2007.

Group A comprised patients in whom sternal closure was performed by the use of peristernal steel bands combined
with peristernal wires. In group B, patients in whom conventional closure was performed were included.

2.1. Inclusion criteria

Patients of 18 years of age or older with one or more of the following criteria: age ≥ 70 years; morbid obesity (body mass index (BMI) ≥ 29 kg/m²); diabetes mellitus (DM) (requiring medical treatment with oral hypoglycemics or insulin); chronic obstructive pulmonary disease (COPD); chronic renal failure (CRI) (preoperative creatinine level ≥ 1.8 mg/dl); poor bone quality, defined as the surgeon’s subjective appreciation regarding the unfavorable characteristics of the sternum: inadequate sternal quality (frangible sternum), presence of sternal fractures, and paramedian sternotomy and transverse intraoperative fractures; reoperations; use of one or two internal mammary arteries; parasternal ‘weaving’ defined as use of the Robiseck technique to reinforce the sternal closure.

The dependent variables considered in the study were: sternal dehiscence and mediastinitis. The objective of the study was to evaluate if the type of sternal closure was associated with the appearance of these complications.

2.2. Surgical technique

The placing of sternal bands for closure after sternotomy requires steel bands (Sternumband® – Ethicon®) and a device designed to adjust the final band tension (Sternumband Tensor).

In each patient, two or three bands were placed depending on the length of the sternum and were placed below the manubrium, corresponding to the 2nd, 3rd and 4th intercostal spaces.

By means of electrocautery use, the pectoral union to the sternum is released in each selected space for band placing, a space through which the band passes is opened (Fig. 1).

Once performed, 2–3 conventional wire stitches are placed and passed trans-sternally in the manubrium.

1. The steel bands are then advanced through the previously performed perforations in the intercostal space. The two ends of each band are left repaired until the placement of all bands is completed. In most cases, two peristernal wire stitches are placed in the 5th and 6th intercostal spaces to complete closure (Figs. 2 and 3).
2. Once the wire stitches and bands are set, device adjustment proceeds.
3. The bands are adjusted with the tensor (device designed for this matter) until complete sternal closure is achieved (Fig. 4).
4. Finally, adequate tension is delivered to the already placed wire stitches at the manubrium and inferior intercostal spaces (Fig. 5).

If during the initial phase of the sternotomy an inadequate aperture was performed, or if the surgeon considers that the sternum is too weak and of poor quality, then, and as a previous step to the placing of bands or conventional wires, a uni or bilateral sternal ‘weaving’ is performed.

Fig. 1. The pectoral union to the sternum is released by electrocautery in each selected space for band placing.

Final results are seen in the chest X-ray taken in the immediate postoperative time at the ICU (Fig. 6).

2.3. Statistical analysis

The information was processed in the SPSS® versión 15 statistical package. The univariate analysis is presented with frequencies distribution and central and dispersion tendency values. The bivariate analysis to compare and
find differences between both groups was performed with non-parametric statistical techniques such as the $\chi^2$ and Mann–Whitney $U$-tests. The odds ratio (OR) values were calculated with their respective 95% confidence intervals (CI). A logistic regression analysis was performed to evaluate the multivariated participation of the risk factors with the presentation of the dependent variables. A $P$-value $<0.05$ was considered for statistical significance.

3. Results

A total of 621 patients were included, 300 in the steel bands (group A) and 321 in the conventional (group B). The median age for the whole population was 68 years (IQR 57–73 years) and 59.1% were males. The most frequently
performed surgery was CABG in 62.5%; valvular repair or replacement in 16.3%; 13.8% had combined cardiac surgery. In the total population, sternal dehiscence was present in 3.9% (24), mediastinitis in 2.7% (17), and death in 0.5% (3). No complications were related to the use of steel bands.

The demographic and clinical characteristics, the procedures performed and the risk factors of the patients in each group and their comparison are shown in Table 1. Comparative results of patients with sternal weaving are independently shown in Table 2.

The bivariate analysis demonstrated a statistically significant higher frequency and risk of sternal dehiscence associated to conventional sternal closure (OR 2.91, CI 95% 1.14–7.43, P = 0.020). No statistically significant differences in the frequency and risk of mediastinitis between both groups was found (OR 2.29, CI 95% 0.797–6.583, P = 0.09).

When analyzing the presence of sternal dehiscence in each group, the risk factors associated with its presentation in group A were a BMI 29 kg/m² and mediastinitis (OR 292.8, CI 95% 1.15–265.5, P = 0.002) and sternal dehiscence (OR 586, CI 95% 43.7–7852.9, P = 0.000). In group B, mediastinitis was associated with poor bone quality (OR 102, CI 95% 16.8–712.9, P = 0.000), the presence of more than two risk factors (OR 5.13, CI 95% 1.24–4.4, P = 0.01), and sternal dehiscence (OR 59.8, CI 95% 13.2–292.8, P = 0.000).

### 4. Discussion

Currently, conventional closure of median sternotomy is performed by placing simple steel wire stitches. Due to their caliber, these wires can cut through bone causing a transverse separation, especially in patients with poor bone quality, inadequate sternal aperture, patients under prolonged mechanical ventilation or the presence of pre- or postoperative infection. Sternal dehiscence generally occurs within the first two postoperative weeks. One of the most important risk factors to prevent sternal dehiscence is to avoid uneven movement of the sternal plates, which is generated by inadequate apposition of sternal borders. The literature suggests that stable and sustained sternal approximation decreases these complications significantly [11, 12].

Some techniques and the use of different materials pretend to optimize sternal closure decreasing the possibility of complications, especially dehiscence and mediastinitis [4–6, 8, 12, 13]. Peristernal steel bands are within this group of techniques and materials, they are inexpensive, and have a simple delivery technique, are easily reproducible and risk free for the patient. The expected benefits with their use is founded upon achieving a more adequate distribution and lower tensile strength force on the sternum, generating more stability and less cut or fracture possibilities [4, 11, 14, 15].

A cohort of 621 patients under cardiovascular surgery with risk factors for sternal dehiscence and mediastinitis with sternal closure performed by conventional technique in one group and with the use of steel bands in the other group was evaluated in this study. The results obtained show that sternal closure with steel bands (Sternumband®) in patients with the described risk factors presented less dehiscence and mediastinitis than those conventionally closed. These results have a major impact when taking into account that the group of patients with band closure were older, had higher BMI, a greater number of co-morbidities and the primary cardiac procedure was more complex. Even when patients with sternal weaving were separately analyzed and compared between groups A and B, it was evident that patients in group A had better results in terms of complications even though they presented more associated risk factors. Therefore, the results strongly support the use of steel sternal bands to prevent complications related to the sternal closure in high-risk patients undergoing cardiac surgery.

In the present study, it was shown, in a statistically significant manner, that the use of steel bands decreases

### Table 1

General description and comparison of patients from each group according to the type of sternal closure

<table>
<thead>
<tr>
<th>Age, years</th>
<th>Group A Steel bands closure</th>
<th>Group B Conventional closure</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>68 (59.25–73)</td>
<td>67 (58–72)</td>
<td>0.036*</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.3 (151)</td>
<td>67.3 (216)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Female</td>
<td>47.9 (149)</td>
<td>32.7 (105)</td>
<td></td>
</tr>
<tr>
<td>Procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CABG</td>
<td>59.3 (178)</td>
<td>65.4 (210)</td>
<td>0.11</td>
</tr>
<tr>
<td>Combined surgery</td>
<td>20.3 (61)</td>
<td>7.8 (25)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Valve repair or replacement</td>
<td>11 (33)</td>
<td>21.2 (68)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Risk factors (inclusion criteria)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age &gt;70 years</td>
<td>38.6 (116)</td>
<td>30.8 (99)</td>
<td>0.04*</td>
</tr>
<tr>
<td>Morbid obesity</td>
<td>27.3 (82)</td>
<td>12.1 (39)</td>
<td>0.00*</td>
</tr>
<tr>
<td>BMI ≥ 29 kg/m²</td>
<td>23 (69)</td>
<td>22.7 (73)</td>
<td>0.93</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>29 (87)</td>
<td>14.6 (47)</td>
<td>0.00*</td>
</tr>
<tr>
<td>COPD</td>
<td>6.7 (20)</td>
<td>4 (13)</td>
<td>0.14</td>
</tr>
<tr>
<td>CRF</td>
<td>33.3 (100)</td>
<td>2.8 (9)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Reinterventions</td>
<td>4.3 (13)</td>
<td>2.8 (9)</td>
<td>0.30</td>
</tr>
<tr>
<td>Mammary use</td>
<td>45.6 (137)</td>
<td>66.04 (212)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Sternal 'weaving'</td>
<td>12.7 (38)</td>
<td>25.2 (81)</td>
<td>0.00*</td>
</tr>
<tr>
<td>More than two risk factors</td>
<td>66.7 (200)</td>
<td>38.3 (123)</td>
<td>0.00*</td>
</tr>
<tr>
<td>Complications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternal dehiscence</td>
<td>2 (6)</td>
<td>5.6 (18)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>1.7 (5)</td>
<td>3.7 (12)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*Values expressed in median and interquartile range.
*Statistical significance (P < 0.05).
the frequency of postoperative sternal dehiscence. These results are in agreement with what was previously reported by Bhattacharya et al. [9], where the incidence of sternal dehiscence was significantly higher in conventional sternal closure when compared to steel band closure (3.78% vs. 0.76%). It is then clear that the type of closure by itself has an association with the presentation of sternal dehiscence, favoring the use of steel bands for sternal closure of sternotomy in patients with one or more risk factors for this complication.

Even though the steel band closure group of patients presented with less cases of mediastinitis (n = 5) compared to the conventional closure group (n = 12), statistical significance was not achieved possibly due to the sample size and given that in our service, patients who present with sternal dehiscence are surgically intervened in an early stage to prevent progression towards infection, respiratory failure and prolonged hospital stay. Once again, the relevance of this finding is greater taking into account that the group of patients closed with steel bands had a greater preoperative clinical involvement, demonstrated by the presence of a higher number of risk factors (age, obesity, poor bone quality and pathologies other than one major underlying cardiac disease).

In summary, in the present study it was demonstrated that sternal closure with the use of steel bands (Sternumband®) resulted in a statistically significant decrease of sternal dehiscence in the group of patients with preoperative risk factors. It was also shown in a significant manner that sternal dehiscence increases the risk of mediastinitis. Given the high statistical association between the developments of secondary mediastinitis due to sternal dehiscence, the use of sternal bands could be suggested to decrease the presence of mediastinitis due to dehiscence.

The technique used for peristernal steel band sternal closure is safe for the patient, easily reproducible, inexpensive and caused no additional morbi-mortality.

### References


